# Comparative Decay Resistance of Twenty-five Fijian Timber Species in Accelerated Laboratory Tests

Lynette D. Osborne[1]

ABSTRACT: Specimens from the heartwood of 2–5 trees of each of 25 species of Fijian rain forest timbers were tested by the laboratory soil-block method against two white-rot fungi, *Fomes lividus* (Kalch.) Sacc. and *Pycnoporus coccineus* (Fr.) Bond. and Sing., syn. *Coriolus sanguineus* (L. ex Fr.) G. H. Cunn.; and against two brown-rot fungi, *Lenzites trabea* Pers. ex Fr. and *Coniophora olivacea* (Fr.) Karst. The species most resistant to decay were *Palaquium hornei, Intsia bijuga, Fagraea gracilipes, Syzygium* spp. complex, and *Dacrydium elatum*. Most of the species tested were highly susceptible to decay.

There was a tendency, both among species and within species, for the denser and less water-absorbent wood to be more resistant to decay. Also, the outer heartwood was, in general, more resistant to decay than inner heartwood.

A RECENT STUDY was made of the decay resistance of a number of tropical rain forest timbers of New Guinea (Da Costa and Osborne, 1967). Prior to this there was almost no information on the durability of the rain forest species of New Guinea, or of the East Asian and South Pacific areas in general. Because more and more local timber is now being used in these countries, there is an increasing need for knowledge of the approximate durability of these timber species so that efficient use can be made of the timber available. This situation applies in Fiji, as local timber has not previously been used extensively for permanent structures, and little is known of its performance in service. Unfortunately, although both New Guinea and Fiji have tropical rain forest vegetation, it appears that there are very few species common to both countries, so that information obtained for New Guinea species has little application in the use of Fijian timbers. This fact is a reflection of the great variety of tropical rain forest timbers in the world and emphasizes the need for information on the durability of this large group of timbers.

It is therefore desirable to study the decay resistance of the species occurring most commonly in Fiji so that suitable timber can be selected for a particular use. For example, it is desirable to use the most durable timbers for conditions of high decay hazard, such as for transmission poles, fence posts, sleepers, and bridge timbers. Less durable timbers may be suitable for external joinery, etc., that is, not in ground contact, whereas highly susceptible ones would be unsuitable for any external use in the humid climate without preservative treatment.

One method of obtaining this information is by graveyard stake tests, and a few species are being studied in Fiji in this way (Alston, 1966). However, as these tests take some years to complete, an accelerated laboratory decay test was considered desirable.

## MATERIALS AND METHODS

The methods used in this investigation follow closely those used in the study of 26 New Guinea timbers (Da Costa and Osborne, 1967) to which the reader is referred for more detailed information.

### *Selection of Material*

The 25 Fijian timber species examined for decay resistance in these laboratory tests are listed in Table 1, together with local and family names. Although *Swietenia macrophylla* and *Eucalyptus citriodora* are not native to Fiji,

[1] Division of Forest Products, CSIRO, South Melbourne, Australia. Manuscript received October 27, 1966.

TABLE 1

Timber Species Tested

| TIMBER SPECIES | TRADE NAME | FAMILY |
|---|---|---|
| *Agathis vitiensis* (Seem.) Drake | dakua makadre | Araucariaceae |
| *Alphitonia zizyphoides* (Spreng.) A. Gray | doi | Rhamnaceae |
| *Calophyllum* spp.* | damanu | Guttiferae |
| *Canarium* spp.* | kaunicina, kaunigai | Burseraceae |
| *Casuarina nodiflora* Forst.* | velau | Casuarinaceae |
| *Dacrydium elatum* Wall. | yaka | Podocarpaceae |
| *Endospermum macrophyllum* (Muell. Arg.) Pax et Hoffm. | kauvula | Euphorbiaceae |
| *Eucalyptus citriodora* Hook. | lemon scented gum | Myrtaceae |
| *Fagraea gracilipes* A. Gray | buabua | Loganiaceae |
| *Garcinia myrtifolia* A. C. Smith | laubu | Guttiferae |
| *Gonystylus punctatus* A. C. Smith | mavota | Gonystylaceae |
| *Heritiera ornithocephala* Kosterm. | rosarosa | Sterculiaceae |
| *Intsia bijuga* (Colebr.) O. Kuntze | vesi | Leguminosae |
| *Myristica* spp.* | kaudamu | Myristicaceae |
| *Palaquium fidjiense* Pierre* | bauvudi | Sapotaceae |
| *Palaquium hornei* (Hartog ex Baker) Dubard | sacau | Sapotaceae |
| *Parinari insularum* A. Gray | sa | Rosaceae |
| *Podocarpus javanica* (Burm. f.) Merr. | aumunu | Podocarpaceae |
| *Podocarpus neriifolius* D. Don | kuasi | Podocarpaceae |
| *Podocarpus vitiensis* Seem. | dakua salusalu | Podocarpaceae |
| *Serianthes myriadenia* Planch. | vaivai-ni-veikau | Leguminosae |
| *Swietenia macrophylla* King | mahogany | Meliaceae |
| *Syzygium* spp. complex* | yasiyasi | Myrtaceae |
| *Terminalia catappa* L. | tivi | Combretaceae |
| *Trichospermum richii* (A. Gray) Seem. | mako | Tiliaceae |
| *Eucalyptus microcorys* F. Muell.† | tallowwood | Myrtaceae |
| *Eucalyptus obliqua* L'Herit.† | messmate | Myrtaceae |
| *Pinus radiata* D. Don† | radiata pine | Pinaceae |
| *Pseudotsuga menziesii* (Mirb.) Franco† | Douglas fir | Pinaceae |
| *Tectona grandis* L.f.† | teak | Verbenaceae |

* Groups consisting of more than one botanical species but regarded as one commercial species.
† Reference timbers of known durability included for comparison.

they have been listed with the other species, as they have been grown in plantations in Fiji for some years.

Timber was collected in Fiji for each species, but often after testing had begun subsequent examination of botanical material showed that there were more than one botanical species within the "species" collected, two or more genera sometimes being represented. Wherever these species have been found to be very similar in appearance in the field, in anatomical structure, physical and strength properties, and durability, the mixture has been regarded as one commercial species. These species mixtures are indicated in Table 1 and are discussed further under "Results." In cases where a species differed appreciably from the main species of the group, it has been omitted.

As these decay tests give comparative results only, five reference timbers, whose durability and performance in service are well known and which represent a wide range of durability, were included and are also listed in Table 1.

As a general rule, specimens from five separate trees were tested for each timber species. However, this number was not always available and smaller numbers of trees were sampled for a few species (see Table 2). The timber was shipped in the form of green logs, and then a pith-to-bark billet measuring approximately 24 inches longitudinally and 6 inches tangentially was cut from each tree, the

TABLE 2

PROPERTIES AND DECAY RESISTANCE OF SPECIES TESTED*

| TIMBER SPECIES | NO. OF TREES | WOOD PROPERTIES: Basic Density (lb/cu ft) | WOOD PROPERTIES: Water Uptake (%) | PERCENTAGE WEIGHT LOSS** CAUSED BY TEST FUNGUS: *Fomes lividus* | *Pycnoporus coccineus* | *Lenzites trabea* | *Coniophora olivacea* |
|---|---|---|---|---|---|---|---|
| *Palaquium hornei* | 4 | **54.5** | **22.4** | **0.5** | **0.2** | **−0.1** | **0.1** |
| | | 51.0–57.0 | 21.4–23.7 | 0.2–0.9 | −0.1–0.8 | −0.2–0.0 | −0.1–0.2 |
| *Eucalyptus microcorys*† | 5 | **54.0** | **19.2** | **0.6** | **1.2** | **0.2** | **0.5** |
| | | 52.2–56.3 | 18.5–20.1 | 0.3–0.9 | 0.5–2.0 | 0.0–0.6 | −3.2–3.8 |
| *Intsia bijuga* | 4 | **46.0** | **28.3** | **2.4** | **0.2** | **0.0** | **0.2** |
| | | 43.0–50.8 | 23.6–31.4 | 0.0–8.1 | 0.0–0.4 | 0.0–0.2 | 0.0–0.4 |
| *Fagraea gracilipes* | 2 | **50.8** | **17.5** | **0.9** | **1.2** | **1.6** | **1.8** |
| | | 49.1–51.9 | 17.3–17.8 | 0.7–1.2 | 0.7–1.7 | 1.1–2.2 | 0.3–4.0 |
| *Tectona grandis*† | 5 | **35.7** | **24.9** | **2.6** | **2.0** | **1.2** | **0.3** |
| | | 31.0–38.6 | 19.6–31.3 | 0.2–6.1 | 0.4–5.3 | 0.4–3.0 | 0.0–1.0 |
| *Syzygium* spp. | 15 | **47.7** | **22.5** | **6.3** | **3.1** | **0.6** | **5.7** |
| | | 39.4–55.1 | 18.8–34.1 | 0.2–24.3 | −0.1–21.9 | −0.3–8.7 | −0.2–29.2 |
| *Eucalyptus obliqua*† | 5 | **38.3** | **38.1** | **9.2** | **1.5** | **0.1** | **14.9** |
| | | 35.3–43.6 | 30.7–43.3 | 2.1–18.2 | 0.4–2.6 | −0.5–0.7 | 0.4–23.6 |
| *Dacrydium elatum* | 3 | **34.5** | **46.9** | **6.2** | **10.1** | **1.8** | **8.3** |
| | | 31.2–38.2 | 35.8–84.7 | 0.6–16.0 | 3.3–20.1 | −0.5–8.2 | −0.3–22.6 |
| *Podocarpus neriifolius* | 4 | **32.5** | **43.1** | **4.4** | **1.0** | **7.8** | **16.6** |
| | | 29.3–35.9 | 30.5–53.8 | 1.3–8.3 | −0.2–4.5 | 0.0–13.9 | 4.3–22.5 |
| *Garcinia myrtifolia* | 5 | **41.9** | **39.2** | **13.2** | **8.8** | **1.9** | **6.9** |
| | | 37.3–46.2 | 35.8–46.6 | 2.1–29.9 | 0.9–27.5 | 0.4–6.3 | 0.4–39.6 |
| *Heritiera ornithocephala* | 5 | **43.1** | **32.8** | **13.9** | **9.0** | **2.3** | **6.3** |
| | | 33.2–50.4 | 23.0–51.0 | 4.2–28.9 | 2.3–27.0 | 0.4–6.8 | 0.0–17.5 |
| *Swietenia macrophylla* | 5 | **27.8** | **38.5** | **19.5** | **5.4** | **2.6** | **5.1** |
| | | 24.3–29.6 | 33.5–43.0 | 13.8–25.6 | −0.2–12.7 | −0.2–10.6 | −0.2–13.0 |
| *Palaquium fidjiense* | 5 | **25.9** | **56.3** | **15.7** | **10.0** | **2.7** | **6.3** |
| | | 20.9–29.4 | 46.1–67.0 | 2.8–28.1 | 0.6–24.3 | −0.3–14.5 | −0.3–28.4 |
| *Serianthes myriadenia* | 5 | **26.8** | **46.3** | **26.0** | **9.1** | **6.3** | **14.1** |
| | | 22.3–30.2 | 39.8–54.9 | 10.0–50.1 | 1.2–19.4 | 0.6–21.6 | 1.0–35.2 |
| *Pseudotsuga menziesii*† | 5 | **26.0** | **41.5** | **10.6** | **4.4** | **19.0** | **32.2** |
| | | 23.0–28.0 | 35.0–48.5 | 6.4–16.5 | 1.4–12.4 | 14.3–25.5 | 27.0–37.0 |
| *Calophyllum* spp. | 5 | **31.9** | **46.2** | **22.6** | **14.2** | **8.7** | **21.4** |
| | | 23.5–38.6 | 33.8–65.2 | 9.6–35.2 | 2.0–27.3 | 0.5–25.9 | −0.7–41.0 |
| *Casuarina nodiflora* | 4 | **52.9** | **31.8** | **19.7** | **26.5** | **5.1** | **18.2** |
| | | 51.0–54.0 | 24.6–40.4 | 13.6–26.8 | 14.4–39.4 | −0.5–9.1 | 5.9–28.3 |
| *Eucalyptus citriodora* | 4 | **41.5** | **42.4** | **24.4** | **27.9** | **7.8** | **18.6** |
| | | 30.8–57.3 | 21.6–71.2 | 4.4–42.5 | 2.8–63.6 | 0.5–18.9 | 1.2–36.4 |
| *Podocarpus vitiensis* | 5 | **24.2** | **72.2** | **13.3** | **21.2** | **17.8** | **27.8** |
| | | 22.6–25.7 | 44.4–99.5 | 8.9–18.8 | 14.7–28.0 | 8.2–21.3 | 23.6–31.0 |
| *Alphitonia zizyphoides* | 2 | **32.6** | **43.4** | **32.9** | **33.8** | **10.3** | **10.6** |
| | | 30.3–34.8 | 39.3–50.6 | 28.5–41.8 | 28.1–39.7 | 6.2–12.7 | 0.0–25.6 |
| *Agathis vitiensis* | 5 | **29.0** | **73.0** | **21.5** | **24.0** | **28.7** | **27.0** |
| | | 26.1–32.9 | 41.8–122.6 | 16.6–25.1 | 15.0–28.4 | 17.9–35.3 | 18.5–34.3 |
| *Parinari insularum* | 5 | **38.8** | **51.7** | **29.6** | **31.7** | **16.9** | **27.4** |
| | | 34.0–43.7 | 42.0–62.1 | 19.6–41.3 | 20.3–40.6 | 9.2–25.8 | 21.7–30.1 |
| *Terminalia catappa* | 4 | **25.1** | **57.0** | **40.6** | **32.6** | **17.2** | **25.0** |
| | | 16.9–32.8 | 43.8–67.7 | 28.7–58.1 | 24.0–43.5 | 4.7–26.3 | 10.8–34.3 |

TABLE 2 (*continued*)

| TIMBER SPECIES | NO. OF TREES | WOOD PROPERTIES: Basic Density (lb/cu ft) | WOOD PROPERTIES: Water Uptake (%) | PERCENTAGE WEIGHT LOSS** CAUSED BY TEST FUNGUS: *Fomes lividus* | *Pycnoporus coccineus* | *Lenzites trabea* | *Coniophora olivacea* |
|---|---|---|---|---|---|---|---|
| *Gonystylus punctatus* | 4 | **35.3** 29.9–41.6 | **54.4** 48.4–60.4 | **29.3** 25.1–33.9 | **32.0** 23.1–37.7 | **28.6** 19.8–38.6 | **31.0** 25.0–36.7 |
| *Podocarpus javanica* | 3 | **27.7** 24.8–28.8 | **103.5** 39.0–149.2 | **22.0** 18.5–25.2 | **32.0** 28.4–37.0 | **35.8** 24.9–44.5 | **31.3** 27.0–34.9 |
| *Pinus radiata*† (sapwood) | 5 | **28.8** 25.6–32.3 | **80.4** 75.3–84.9 | **23.7** 21.4–27.5 | **27.2** 20.8–36.0 | **33.1** 24.4–39.7 | **39.7** 38.2–41.0 |
| *Canarium* spp. | 5 | **29.4** 26.1–33.8 | **49.7** 35.0–77.4 | **48.0** 32.1–60.1 | **28.9** 21.0–47.4 | **24.7** 9.9–35.6 | **30.4** 17.4–40.0 |
| *Endospermum macrophyllum* | 5 | **25.1** 18.1–29.5 | **65.0** 52.5–90.7 | **41.9** 31.1–55.4 | **44.0** 37.6–53.9 | **33.8** 25.8–48.6 | **36.4** 31.6–39.6 |
| *Myristica* spp. | 5 | **26.1** 22.7–32.5 | **100.4** 73.7–123.6 | **54.1** 49.8–60.1 | **44.2** 36.4–63.3 | **29.0** 19.0–39.2 | **39.6** 33.6–46.0 |
| *Trichospermum richii* | 4 | **17.4** 11.6–22.2 | **198.2** 128.7–270.3 | **60.7** 48.9–70.2 | **55.7** 42.2–72.9 | **31.4** 18.2–49.7 | **46.1** 38.5–53.9 |

* Values represent the mean for two specimens (inner and outer heartwood) from each tree and the range. Species arranged in decreasing order of overall mean for four fungi.
** Incubation period of 8 weeks (12 weeks for *P. coccineus*).
† Reference timbers of known durability included for comparison.

radial measurement varying with each tree. The material was air-dried before a quarter-sawn plank (3/8 inch thick) was removed from each billet for testing.

Two specimens were tested from each tree, for each fungal species. It has been shown in many timbers (Scheffer and Duncan, 1947; Findlay, 1956; Rudman and Da Costa, 1959; Rudman, 1964) that the outermost heartwood is the most durable wood in the tree, and so a sample was taken from this position, as well as one closer to the pith, representing the rest of the heartwood which would be used commercially. The test blocks measured 3/4 inch parallel to the fibres, 1 3/8 inches radially, and 3/8 inch tangentially, the longest dimension being in the radial direction so as to sample the maximum variation in durability. The sapwood was not normally tested, as it is usually nondurable and can be readily treated with preservatives if necessary. However, in some trees the sapwood-heartwood boundary could not be defined or there appeared to be little or no heartwood, and in these cases sapwood was tested as well as, or instead of, heartwood, inasmuch as this would be the timber used commercially.

*Decay Tests*

A soil-block method was used in which cylindrical 8-oz glass jars (2 3/4 inches diameter; 3 1/4 inches high) with unlined metal screw caps were partly filled with 120 g of forest loam soil at 60% moisture content. Two feeder strips (1 3/4 × 3/4 × 1/16 inch) of beech (*Fagus sylvatica*) sapwood were placed on the soil and, after sterilization, were inoculated with the particular test fungus. After fumigation with propylene oxide (Hansen and Snyder, 1947), two blocks, representing the inner and outer heartwood of the one tree, were placed in each jar, the largest face resting on the fungal mycelium. The percentage loss of weight, as compared with the air-dry initial weight, was used as a measure of the amount of decay.

Four test fungi were used: *Coniophora olivacea* (Fr.) Karst. (DFP 1779) and *Lenzites trabea* Pers. ex Fr. (DFP 8845), both brown-rot fungi, and *Pycnoporus coccineus* (Fr.) Bond. and Sing. (syn. *Coriolus sanguineus* [L. ex Fr.] G. H. Cunn.) (DFP 2544) and *Fomes lividus* (Kalch.) Sacc. (DFP 7904), two white-rot fungi. The incubation period was 12 weeks for *P. coccineus* and 8 weeks for the other fungi.

After completion of the main decay test, all blocks showing less than 10% weight loss after attack by *C. olivacea* or *F. lividus* were subjected to a further 16 weeks' incubation with these two fungi.

### *Measurement of Basic Density and Water Uptake*

It has been shown for 26 New Guinea timber species (Da Costa and Osborne, 1967) that there is a correlation between percentage weight loss and basic density and, more particularly, between percentage weight loss and water uptake. Therefore, measurements of these two properties were made on two specimens from each tree. The water uptake was measured by standing air-dry blocks, end grain down, in 1/8 inch of water for 24 hours and calculating the increase in moisture content as a percentage of the oven-dry weight. The approximate basic density was calculated using the oven-dry weight and the "green" volume after blocks had been pressure-impregnated with water and allowed to swell for 48 hours.

## RESULTS

The basic density and water uptake measurements, together with the decay figures, are presented in Table 2. As some timber species show considerable variation, both among trees and between the two radial positions within a tree, minimum and maximum values have been included, as well as the mean figure. As expected, the outer heartwood was generally more resistant than was heartwood closer to the pith. In 70% of 416 relevant comparisons the percentage weight loss of the outer heartwood was lower.

*Palaquium hornei* proved extremely durable, being comparable in resistance with the very durable reference timber *Eucalyptus microcorys*. *Intsia bijuga* and *Fagraea gracilipes* also were durable, with several other timbers showing moderate durability. However, the remaining species showed poor resistance, most being highly susceptible.

It can be seen from Table 2 that for each timber species there is a variation in the amount of decay depending on the particular test fungus, as well as a variation between trees. Because of these variations it is difficult to obtain a meaningful single-figure estimate of the relative decay resistance of the timber species. In Tables 2 and 3 the timber species are arranged in order of decreasing resistance based on the overall mean for the four fungi. However, other criteria may be used, such as the mean amount of decay caused by the most destructive fungus for each timber species, or the mean ranking for each timber (i.e., for each fungal species the timbers are ranked 1–30 in order of percentage weight loss, and the mean of these rankings for the four comparisons is obtained). Mean ranking is useful in cases where the test fungi show different rates of decay, *L. trabea* in particular producing almost consistently lower decay losses than the other three fungi. The advantages and disadvantages of the various methods have been discussed by Da Costa and Osborne (1967). It can be seen, however, that no matter which criterion is used the general order of the timber species does not alter appreciably (Table 3).

Results for the second decay test of the more durable species are shown in Table 4. *Palaquium hornei* and *Fagraea gracilipes* still proved to be durable, whereas the remaining timbers showed quite appreciable weight losses, at least against the white-rot fungus *F. lividus*. An interesting result is that *Intsia bijuga* showed a great increase in weight loss after a further 16 weeks' incubation with *F. lividus*.

As has been stated it was found, after testing had begun, that some timbers consisted of more than one botanical species (see Table 1). It is emphasized that these mixed groups include only species which are regarded as being very similar in many respects, including natural durability. However, the following comments indicate the actual species tested.

Of five trees tested of *Calophyllum* spp., three were identified as *C. vitiense* Turr. (mean percentage weight losses: 20.0, 15.7, 5.4) and two as *C. leucocarpum* A. C. Smith (weight losses: 20.4, 22.1%). The *Canarium* spp. group consisted of three trees of *C. smithii* Leenh., one tree of *C. vitiense* A. Gray, and one tree denoted as *C. sp. aff. C. vitiense,* all five trees

TABLE 3

RELATIVE DECAY RESISTANCE BY VARIOUS CRITERIA

| TIMBER SPECIES | PERCENTAGE WEIGHT LOSS | | MEAN RANKING* |
|---|---|---|---|
| | Overall Mean | Mean for Worst Fungus | |
| *Palaquium hornei* | 0.2 | 0.5 | 1.0 |
| *Eucalyptus microcorys* | 0.6 | 1.2 | 3.5 |
| *Intsia bijuga* | 0.7 | 2.4 | 2.2 |
| *Fagraea gracilipes* | 1.4 | 1.8 | 4.8 |
| *Tectona grandis* | 1.5 | 2.6 | 5.2 |
| *Syzygium* spp. complex | 3.9 | 6.3 | 7.0 |
| *Eucalyptus obliqua* | 6.4 | 14.9 | 8.0 |
| *Dacrydium elatum* | 6.6 | 10.1 | 10.2 |
| *Podocarpus neriifolius* | 7.4 | 16.6 | 9.8 |
| *Garcinia myrtifolia* | 7.7 | 13.2 | 10.2 |
| *Heritiera ornithocephala* | 7.9 | 13.9 | 10.8 |
| *Swietenia macrophylla* | 8.2 | 19.5 | 10.5 |
| *Palaquium fidjiense* | 8.7 | 15.7 | 12.0 |
| *Serianthes myriadenia* | 13.9 | 26.0 | 15.5 |
| *Pseudotsuga menziesii* | 16.6 | 32.2 | 16.8 |
| *Calophyllum* spp. | 16.7 | 22.6 | 17.5 |
| *Casuarina nodiflora* | 17.4 | 26.5 | 16.0 |
| *Eucalyptus citriodora* | 19.7 | 27.9 | 18.5 |
| *Podocarpus vitiensis* | 20.0 | 27.8 | 18.0 |
| *Alphitonia zizyphoides* | 21.9 | 33.8 | 20.5 |
| *Agathis vitiensis* | 25.3 | 28.7 | 20.0 |
| *Parinari insularum* | 26.4 | 31.7 | 21.8 |
| *Terminalia catappa* | 28.8 | 40.6 | 22.8 |
| *Gonystylus punctatus* | 30.2 | 32.0 | 24.0 |
| *Podocarpus javanica* | 30.3 | 35.8 | 24.2 |
| *Pinus radiata* (sapwood) | 30.9 | 39.7 | 24.2 |
| *Canarium* spp. | 33.0 | 48.0 | 24.0 |
| *Endospermum macrophyllum* | 39.0 | 44.0 | 27.8 |
| *Myristica* spp. | 41.7 | 54.1 | 28.0 |
| *Trichospermum richii* | 48.5 | 60.7 | 29.2 |

* For each fungal species, the timbers were ranked 1–30 in order of increasing mean percentage weight loss and the mean of these rankings for the four comparisons was obtained.

showing very similar durability (weight losses: 36.3, 34.9, 28.8; 31.5; 33.3%). Amongst the four trees of *Casuarina nodiflora* sampled was one tree identified as *Gymnostoma vitiense* L. A. S. Johnson, which showed a slightly higher mean percentage weight loss (23.1 cf. 13.0, 18.6, 17.4). However, no conclusions can be drawn from results for one tree of a species. Decay figures were similar for all trees of *Myristica* spp., which consisted of two trees of *M. chartacea* Gillespie (47.7, 39.8%), one tree of *M. castanaefolia* A. Gray (39.1%) and two trees of *M. hypargyrea* A. Gray (40.2, 41.8%). Of five trees tested of the *Palaquium fidjiense* group, two trees were identified as *Palaquium* n.sp., but all showed such similar decay losses that the two species could not be distinguished on durability in these tests.

In the case of the *Syzygium* spp. complex, apparently a number of botanical species appear very similar in the field, inasmuch as nine different species were received under the trade name of "yasiyasi." On the basis of field characteristics and physical properties of the timber, these species can be divided into two main groups, as shown in Table 5, which includes the mean percentage weight loss for all four fungi for each tree. As there is some variation in the mean percentage weight losses for different trees within a species, and within each group, and as only one or two trees were tested for many of the species, no differentiation

TABLE 4

DECAY LOSSES FOR BLOCKS OF DURABLE TIMBERS SUBJECTED TO SECOND DECAY PERIOD

| TIMBER SPECIES | MEAN PERCENTAGE WEIGHT LOSS: *Fomes lividus* 8 weeks | *Fomes lividus* 24 weeks | *Coniophora olivacea* 8 weeks | *Coniophora olivacea* 24 weeks |
|---|---|---|---|---|
| *Palaquium hornei* | 0.5 | 7.5 | 0.1 | 1.3 |
| *Eucalyptus microcorys** | 0.6 | 4.2 | 0.5 | 1.0 |
| *Intsia bijuga* | 2.4 | 32.6 | 0.2 | −0.3 |
| *Fagraea gracilipes* | 0.9 | 6.4 | 1.8 | 4.2 |
| *Tectona grandis** | 2.6 | 22.6 | 0.3 | 2.7 |
| *Syzygium* spp. | 4.0 | 34.2 | 2.1 | 14.3 |
| *Eucalyptus obliqua** | 6.7 | 51.1 | 3.2 | 14.8 |
| *Dacrydium elatum* | 4.3 | 32.3 | 0.3 | 2.8 |
| *Podocarpus neriifolius* | 4.4 | 29.4 | 4.3 | 13.1 |
| *Garcinia myrtifolia* | 5.6 | 51.1 | 1.5 | 17.9 |
| *Heritiera ornithocephala* | 7.0 | 44.6 | 4.2 | 13.1 |
| *Swietenia macrophylla* | — | — | 3.9 | 19.2 |

* Non-Fijian timbers included for comparison.

between the species or groups can be made from these durability results. Although *Acicalyptus myrtoides* belongs to the small-leaf group, tests carried out by the Division of Forest Products, CSIRO, show that this timber has different strength properties from all other species of yasiyasi. However, as far as natural durability is concerned, it is not possible from the present data to distinguish *A. myrtoides* from the other species, since only one tree was tested.

It may be noticed that *Eucalyptus citriodora* showed rather low decay resistance. This is due to the fact that the specimens tested of two trees were sapwood (mean percentage weight losses 37.4 and 31.1 cf. 6.4 and 4.0 for trees where only heartwood was sampled). However, since the sapwood in these trees extended for 4–6 inches from the bark, there would be sapwood present in most timber used for commercial purposes, and so the species will show low durability unless heartwood is carefully selected.

The relationships between percentage weight loss, basic density, and percentage water uptake were investigated, first by using a mean value for each timber species, and then by examining relationships within a species. Statistical analyses showed that the correlations between these factors were very similar to those found by Da Costa and Osborne (1967) for

TABLE 5

DECAY LOSSES FOR INDIVIDUAL TREES OF *Syzygium* SPECIES COMPLEX

| GROUP | BOTANICAL SPECIES | MEAN PERCENTAGE WEIGHT LOSS FOR EACH TREE | | | |
|---|---|---|---|---|---|
| Yasiyasi 1 | *Syzygium nidie* Guill. | 5.8 | 14.9 | 4.6 | |
| (Small-leaf group) | *Eugenia effusa* A. Gray | 1.8 | 0.6 | 6.0 | 0.9 |
| | *Acicalyptus myrtoides* A. Gray | 0.0 | | | |
| | | | | GROUP MEAN | 4.3 |
| Yasiyasi 2 | *S. curvistylum* (Gill) Merr. et Perry | 2.8 | | | |
| (Medium-leaf group) | *S. fijiense* L. M. Perry | 3.5 | | | |
| | *S. brackenridgei* (A. Gray) C. Muell. | 3.8 | | | |
| | *Acicalyptus longiflora* A. C. Smith | 2.6 | | | |
| | *A. eugenioides* (Seem.) Drake | 6.0 | | | |
| | *A. elliptica* A. C. Smith | 4.0 | 1.5 | | |
| | | | | GROUP MEAN | 3.5 |

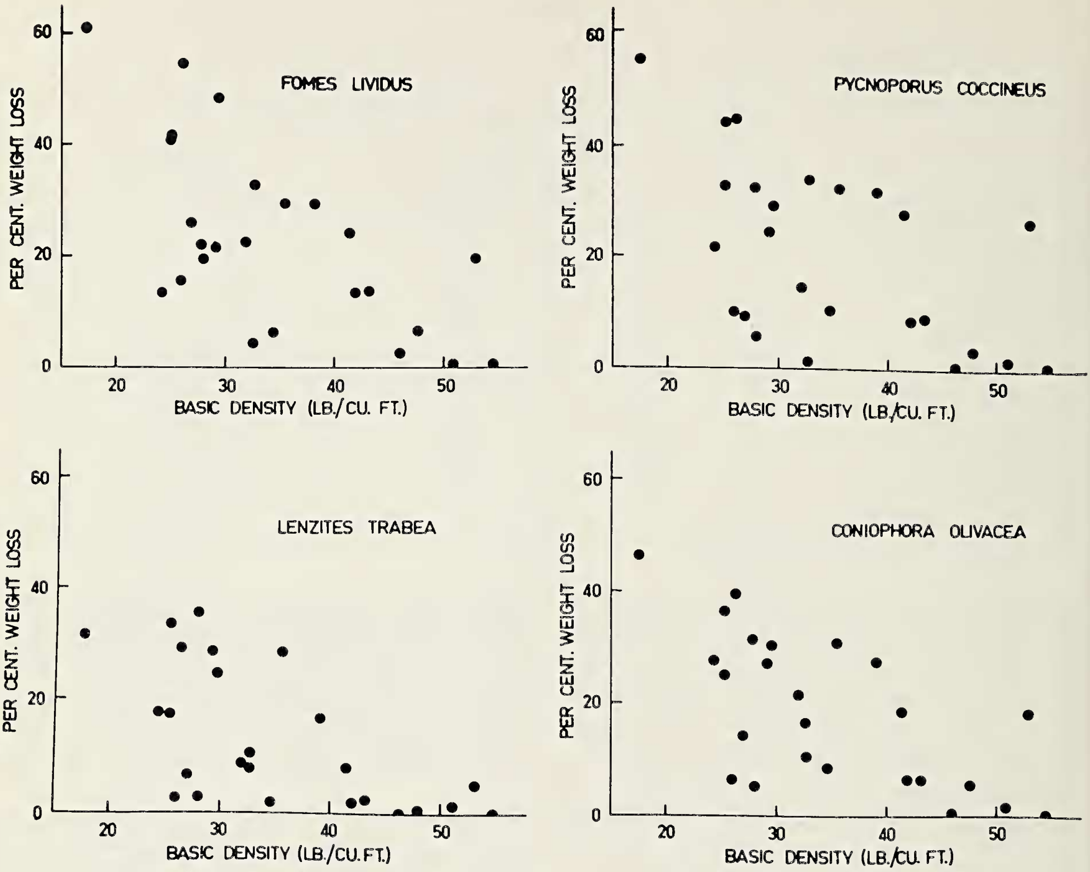


FIG. 1. Relationship of decay resistance to basic density (species means).

26 New Guinea timbers. The scatter diagrams in Figure 1, using species means, indicate an inverse correlation between basic density and percentage weight loss for each of the four test fungi. It may be argued that, even if absolute losses in weight are identical for blocks of different densities, there would be a spurious inverse correlation of density with percentage weight loss. This possibility has been tested statistically, and it has been shown that the absolute weight loss was not constant for all species, and that there was a small ($r = 0.32$) but highly significant correlation between density and absolute weight loss. As with the New Guinea timbers previously tested, there was a tendency for the more water-absorbent species to be more susceptible to decay (Fig. 2). Inasmuch as there was also a correlation between basic density and water uptake, multiple regression analyses were made. These showed that for all four fungi, the percentage water uptake was a better predictor of percentage weight loss than was basic density, as is indicated from a comparison of Figures 1 and 2. The effect of water uptake was significant at the 5% level for *F. lividus* and *L. trabea,* and at the 1% level for *P. coccineus* and *C. olivacea,* whereas the additional effect of basic density was not significant for any of the fungi.

The relationship between basic density and decay resistance also held within the timber species for all four fungi. Because it is not practicable to give detailed results, data are presented for four timber species which showed wide ranges of basic density (Fig. 3). Statistical analyses again showed that the correlations between absolute weight loss (and hence percentage weight loss) and basic density were highly significant in each case. The detailed data suggested a similar correlation between

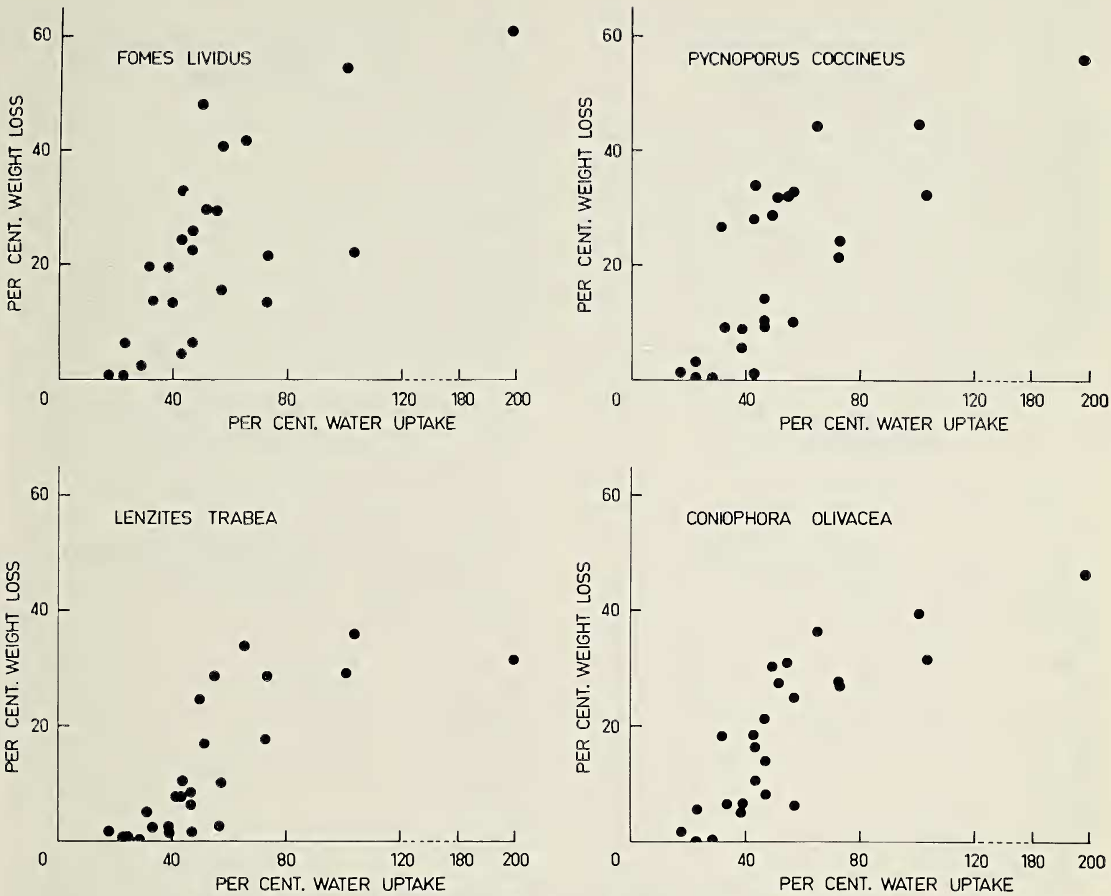


FIG. 2. Relationship of decay resistance to water uptake (species means).

high water absorption and susceptibility to decay within each of these species.

## DISCUSSION

From the data in Tables 2, 3, and 4 it can be seen that *Palaquium hornei* proved extremely durable, even after a second, more severe decay test. Its resistance is comparable with that of the highly durable reference timber, *Eucalyptus microcorys,* which is one of the timbers used in Australia for prolonged service in ground contact. *Intsia bijuga* and *Fagraea gracilipes* were also found to be durable, although *I. bijuga* did not show such high resistance after prolonged exposure to *F. lividus.* Specimens of *I. bijuga* from New Guinea have been tested and shown to have comparable durability to the Fijian samples (Da Costa and Osborne, 1967), and also similar susceptibility to *F. lividus* during a second decay period. This timber has been widely used in ground contact in New Guinea, apparently with satisfactory results, and so the high susceptibility to *F. lividus* may be misleading. *Syzygium* spp. complex, *Dacrydium elatum, Podocarpus neriifolius, Garcinia myrtifolia, Heritiera ornithocephala, Swietenia macrophylla,* and *Palaquium fidjiense* all showed moderate durability, being slightly less resistant than *Tectona grandis,* which does not give extremely long service in the ground although it has an international reputation for durability.

The remaining 16 timbers would probably be too susceptible for use in any situation of high decay hazard, such as ground contact, but a few less susceptible species could possibly give satisfactory service as exposed woodwork,

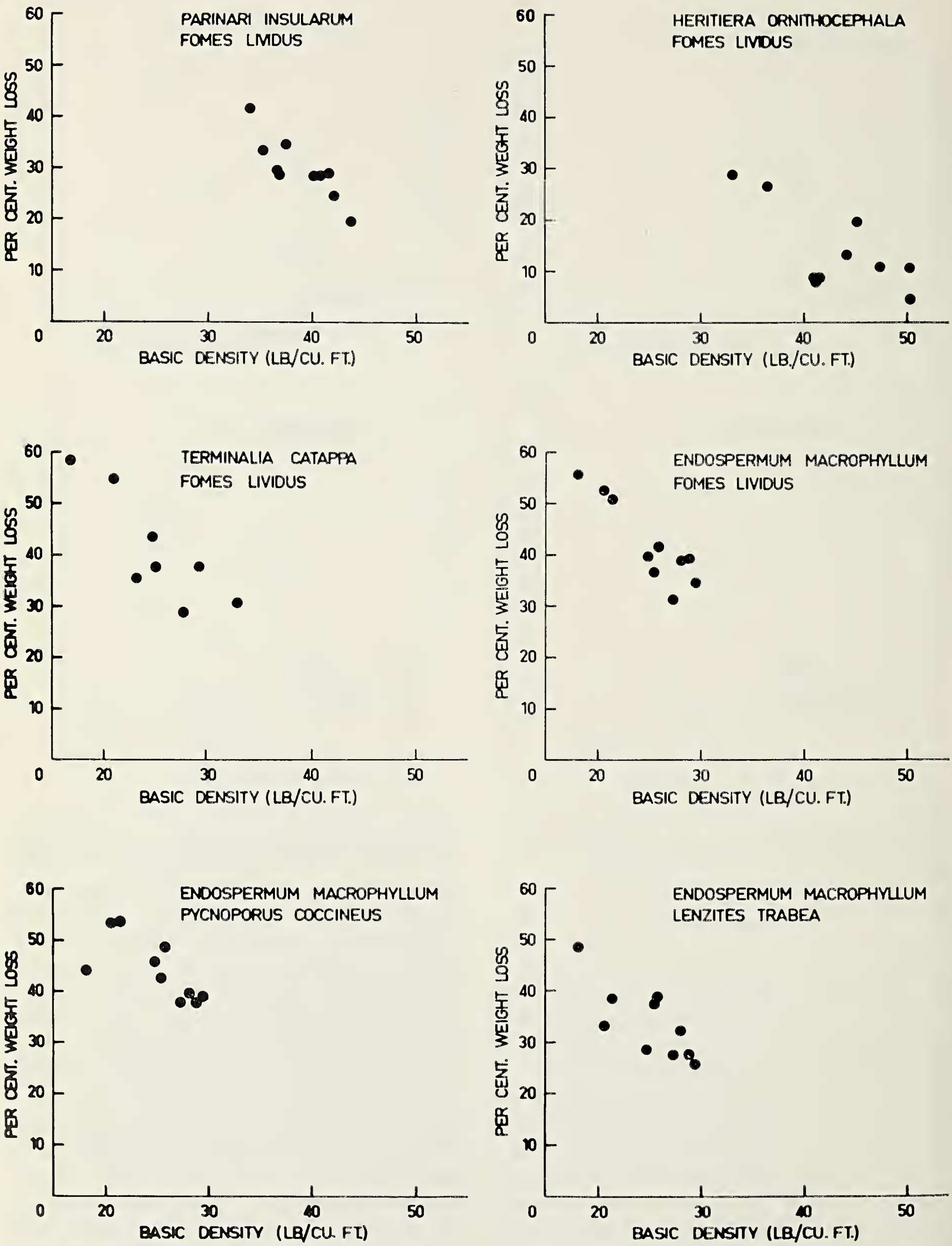


FIG. 3. Intra-specific relationship of decay resistance to basic density (individual specimens).

as does *Pseudotsuga menziesii*. However, those species which are comparable with the highly susceptible *Pinus radiata* sapwood would be unsuitable for external use in humid climatic conditions, unless they were impregnated with a preservative.

Specimens of almost 20 of the species in the present test are, or have been, in graveyard stake tests in Fiji. Although these tests are not complete some comparison can be made between the laboratory and field results (Alston, 1966). In general, there is good agreement between the results of the two types of tests, the timber species ranking in approximately the same order, with only a few exceptions. Specimens of *Garcinia myrtifolia, Palaquium fidjiense,* and *Swietenia macrophylla,* when compared with the other timber species, all showed higher decay resistance in the laboratory tests than they did in the field tests. The reason for this discrepancy is not clear but could possibly be related to rate of wetting. *S. macrophylla,* although not native to Fiji, is an important plantation timber in Fiji, and it is therefore particularly important to note that for this species field test results are not as favourable as laboratory results.

In conclusion, it should be stressed that the relationships obtained in the present tests for the tropical rain forest timbers of Fiji are very similar to those obtained for a group of comparable timbers of New Guinea: notably, that less dense timber species tend to be more susceptible to fungal decay, but, more particularly, that timbers which are highly water-absorbent are more susceptible. It is possible, therefore, that a knowledge of the density of a rain forest timber of which little else is known may be a rough guide to its durability. Again, a majority of trees was shown to have more durable heartwood in the outer zone than in the inner position, although the percentage was not as high as for the New Guinea timbers (70% cf. 86%).


## ACKNOWLEDGMENTS

The author wishes to acknowledge the collaboration of the Department of Forestry, Fiji in collecting material for this investigation, of the Royal Botanic Gardens, Kew in identifying specimens, and of Miss Nell Ditchburne in carrying out the statistical analyses. Thanks are due also to Mr. E. W. B. Da Costa for valuable discussion and to Mr. J. M. Stephenson and Miss Maureen A. Tighe for technical assistance.


## REFERENCES


ALSTON, A. S. 1966. Natural Heartwood Durability. Fiji Timbers and Their Uses, No. 2. Dept. of Forestry, Fiji.

DA COSTA, E. W. B., and LYNETTE D. OSBORNE. 1967. Comparative decay resistance of 26 New Guinea timber species in accelerated laboratory tests. Commonw. For. Rev. 46(1):63–74.

FINDLAY, W. P. K. 1956. Timber decay—a survey of recent work. For. Abstr. 17:317–327, 477–486.

HANSEN, H. N., and W. C. SNYDER. 1947. Gaseous sterilization of biological materials for use as culture media. Phytopathology 37(5):369–371.

RUDMAN, P. 1964. The causes of natural durability in timber. Pt. 16. The causes of variation in decay resistance in jarrah (*Eucalyptus marginata* Sm.). Holzforschung 18:172–177.

——— and E. W. B. DA COSTA. 1959. Variation in extractive content and decay resistance in heartwood of *Tectona grandis* L.f. J. Inst. Wood Sci. 3:33–42.

SCHEFFER, T. C., and CATHERINE G. DUNCAN. 1947. The decay resistance of certain Central American and Ecuadorian woods. Trop. Woods No. 92:1–24.